Gill Sm

National Aeronautics and Space Administration
Goddard Space Flight Center
Contract No. NAS-5-9299

ST - PF - GM - 10495

INTENSITY VARIATIONS OF PROTONS AND ELECTRONS OF THE OUTER RADIATION BELT

by

I. A. Savenko
M. V. Tel'tsov
P. I. Shavrin

(USSR)

30 MAY 1966

ST — PF — GM - 10 495

INTENSITY VARIATIONS OF PROTONS AND ELECTRONS OF THE OUTER RADIATION BELT*

Geomagnetizm i Aeronomiya
Tom 6, No. 2, 377-380,
Izd-vo "NAUKA", 1966.

by I. A. Savenko
M. V. Tel'tsov
P. I. Shavrin

SUMMARY

12927

This paper expounds the results of data processing following the initial analysis of the results of measurements of the outer proton belt conducted by the radiometric devices of the AES "Cosmos-41" and published, alongside with the description of the apparatus, in earlier works [1, 2], covering the period prior to August 1964. The results of this subsequent analysis, presented here, cover the period from August to December 1964.

Author

* * *

The data concerning the radiometric apparatus aboard AES Cosmos-41 are presented in the Table (next page).

The intensity variations of protons with energy 0.4 — 7 Mev, 1- for 3 September, 2- for 19 Sept., 3- for 21 Sept., 4- for 9 October, 5- for 19 December 1964, and the intensities of the magnetic field B (curve 6) and of satellite height above the Earth's surface, h (curve 7) are plotted in Fig. 1 as function of the parameter L. (This parameter L was computed in the dipole approximation and the values $L > 5$ have a conditional character). For the curves 1 — 4 the field intensity B is given by a solid curve. Over this portion of trajectory the angle between the axis n — p of the counter and the lines of force constituted $\sim 60^{\circ}$; in this way the counter registered protons with pitch-angles in the 30 to 90° interval. For the curve 5 the field intensity is shown by dashes and the angle between the magnetic lines of force and the counter's axis constituted $\sim 40^{\circ}$ in this case. The magnetic field intensity increase and the decrease of pitch-angles conditioned the lowering of proton intensity registered on the 19th of December in the outer belt maximum ($L_m = 3.5$).

* VARIATSII INTENSIVNOSTI PROTONOV I ELEKTRONOV VNESHNEGO RADIATSIONNOG POYASA.

T A B L E

PROPERTIES OF THE DETECTORS

TYPE OF DETECTOR	SHIELD	Geometr factor cm^2ster	TYPE AND ENERGY OF REGISTERED PARTICLES
Semiconductor n-p counter with sens.layer constituted of 8 mg/cm^2 SiO^2	200 g/cm^2	0.06	$0,4 \leqslant E_p \leqslant 7$ Mev
Ibid.	20 mg/cm^2	0.07	$3 \leqslant E_p \leqslant 8$ Mev
Cylindr. Scintillator NaJ (Tl)	min 0.18 g/cm^2 Al	6.8*	At direct passage $E_e > 600$ kev $E_p > 10$ Mev
Gas-discharge counters STS - 5	min 0.15 g/cm^2 Al + steel	4.3*	$E_e \geqslant 500$ kev $E_p \geqslant 9$ Mev
SI-ZBG-I	min 0.84 g/cm^2 Al + steel	0.1*	$E_e \geqslant 2$ Mev $E_p \geqslant 25$ Mev
SI-ZBG-II	min 3 g/cm^2 Al		
End-window gas-discharge counters			
SBT-9 No. 1	1 mg/cm^2 mica	0.1 *	$E_e > 25$ kev $E_p > 0,5$ Mev
SBT-9 No. 2	1 mg/cm^2 mica + magnetic shield	0.1	$E_e > 85$ kev $E_p > 0,5$ Mev
SBT-9 No. 3	20 mg/cm^2 Al + 1 mg/cm^2 mica and magnetic shield	0.1	$E_e > 120$ kev $E_p > 3$ Mev

* Here the geometrical factor is isotron in cm^2

From the consideration of the curves for proton intensities it may already be seen in Fig. 1 (next page) that the outer part of the protonosphere undergoes substantial variations beginning with $L \geqslant 5.5$. From the comparison of data on intensity measurements of protons and electrons of the outer radiation belt [2] for various satellite flights the following conclusions may be derived :

a) the greatest temporal intensity variations of electrons for a fixed L take place in the region $L = 5 \div 7$; at the same time the counting rate variations are linked with both, the variation of the spatial position of the belt, and the intensity variation of electrons with energy exceeding the detector's threshold;

b) the temporal variations in the intensity of protons take place only in the outer part of the proton belt, beginning with $L > 4.5$ and increase with the increase of L, whereas the position of the intensity maximum ($L_m = 3.5$) and the intensity of protons in the maximum hardly vary.

These conclusions are in agreement with the works [3, 4]. According to the results of measurements on Explorer-14 [3], the temporal variations of electrons with energies $E_e > 40$ kev and $E_e > 1.6$ Mev reach the value of 10^2; at the same time there is noted a tendency to variation increase as L increases from 2.8 to 4.8, while the intensity of measured protons with energies $E_p > 500$ kev in the region $L = 2.8 - 3.6$ varies substantially less than by a factor of 2.

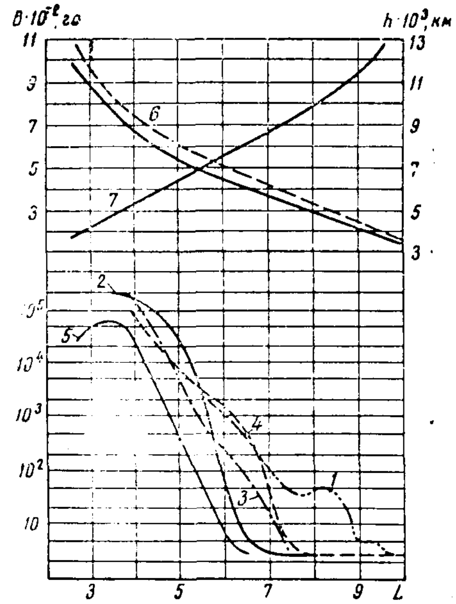

Fig. 1

It is concluded in the work [4] from the data of 15 passages of AES – Explorer-12 through the outer proton belt that the temporal variations do not exceed 30% for protons with energies $E_p > 100$ kev in the region $L < 7$. However, this is not in contradiction with the data obtained on AES Cosmos-41, where the scale of variations reached 10^2 [2], for during measurements on Exporer-12 the 15 days may have been " quiet " for the protonosphere, and besides, the energy threshold of the registered protons is essentially different from that in our case.

Consideration of the relationship between the measurements of proton and electron intensity and their dependence of the geomagnetic setup offers interest. The intensity variations of low-energy protons with energy from

0.4 to 3 Mev on various L-shells (curves 2) are plotted in Fig. 2 according to measurements from 31 August to 4 September and from 16 September to 21 September. Shown there also are the intensity variations of electrons registered by counters SI-ZBG-1 (curves 1) and STS-5 (curves 3). Given in the lower part are the variations of the three-hour K_p- index [5]. It may be seen from the graphs that there is a positive correlation between the temporal intensity variations of protons and electrons, this correlation being stronger for the more energetic electron component. An inverse picture is observed only on L = 10, but here the count of SI-ZBG-1 remained during the entire experiment at the background level of cosmic radiation. Moreover, it may be seen from Fig. 2 that the appearance of significant proton and electron intensity in the region L = 7 ÷ 10 is linked with the increase of magnetic perturbations.

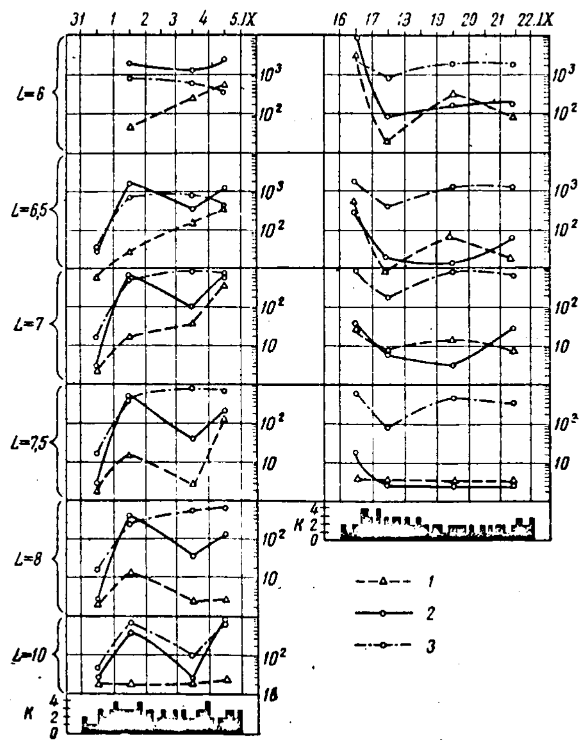

Fig. 2

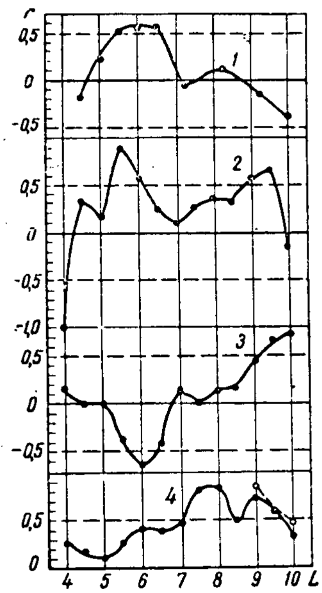

Fig. 3

The dual correlation factors r were computed of the corresponding values in the region L from 4 to 10 with the view of obtaining quantitative estimates of the dependence of temporal intensity variations of electrons and protons [6]. For values $r \gg 0.4$, the relative error in the determination of r, proportional to $n^{-1/2}$ (<u>n</u> being the number of measurements), did not exceed 40%. The results of processing are shown in Fig. 3, where the variation of the correlation factor as a function of L is plotted for the three considered cases. The curve 1 refers to the dependence of the temporal intensity variations of protons with energies 0.4 – 7 Mev, and to the intensity of hard electrons registered by the counter SI-ZBG-1, the curve 3 – to the case of protons and soft electrons registered by the STS-5 counter. It may be seen from the examination of the curves 1 and 2 that an anticorrelation is observed in the variations of the proton and and electron radiation components in the L region from 4 to 4.5, which may be explained by spatial shift of the proton belt ($L = 3.5$) and electron belt maxima ($L_m = 4,5 \div 5.0$), inasmuch as in the region indicated the proton belt has an outer intensity drop, and the electron belt – the inner. Further, for $L = 5.5 \div 9.5$, it may be seen from the curve 2 that the presence of positive correlation exists with a certain decrease of r on $L = 7$. The absence of correlational dependence at $L > 9.5$ is evidence of the fact that energetic electrons were generally not registered at such remote L-shells. For the curve 1 the absence of correlation is observed at still lower shells ($L > 7$).

The curve 3 has an entirely different character. Here, to the contrary, anticorrelation takes place in the region $L < 7$, while on $L > 8.5$ there is a positive correlation. To explain the first event, the difference in the behavior of the soft ($E_e > 40$ kev) and hard ($E_e > 1.6$ Mev) components of electron radiation of the outer radiation belt during magnetic disturbances, observed through the measurements on Explorer-14 [3], may serve as a certain indication. A certain shift in phase was detected by the authors at outer radiation belt at its filling by electrons of the above indicated energies after magnetic disturbance.

The presence of a positive correlation in the intensity variations of protons and soft electrons on $L = 10$ is evidence of a rather frequent registration of simultaneous fluxes of protons and soft electrons near the boundary of the magnetosphere. During the magnetic storm with SC of 30 Sept. 1961 fluxes of protons $\sim 2 \cdot 10^5$ (cm^2 sec·ster)$^{-1}$ with energy $E_p > 140$ kev and electrons $\sim 3 \cdot 10^6$ (cm^2·sec·ster)$^{-1}$ with energy $E_e = 10 \div 35$ kev were registered by the apparatus of Explorer-12 [7]. The authors approximated the integral spectrum of the registered protons by the expression $N(>E) = N_0 E^{-\gamma}$, where $\gamma = 0.8 - 1.05$. We had noted in the work [2] a case of registration on $L = 9.5$ of a proton flux $\sim 10^3$ (cm^2·sec·ster)$^{-1}$ with energy $0.4 - 3$ Mev, accompanied by intensity increase of soft electrons, this case coinciding in time with a geomagnetic storm. Three peaks of proton intensity $\sim 10^3$ (cm^2·sec·ster)$^{-1}$ were registered in all on remote L-shells two of them being attended by magnetic storms. However, in the computations having determined the presence on $L > 9$ of a positive correlation of proton and soft electron intensity, entered all cases of measurements, exceeding the registration threshold (3 cm^{-2}·sec^{-1}·ster^{-1}).

The processing of data on ascertaining the correlational dependence of proton intensity on magnetic disturbance, characterized by the planetary K_p-index [5], was conducted by the same method; this K_p-index was averaged :

a) for the day preceding the measurement time, b) for the current day; c) for 12 hours preceding the measurement time, d) for 3 hours preceding the measurement time.

The strongest correlational dependence was found for the case c); the corresponding curve of correlation factor r variation from parameter L is plotted in Fig. 3 by the curve 4. It is interesting to note that for the case d) on L = 9.10 somewhat greater values of r were obtained than for the case c). (The respective points, joined by dashed line are represented in Fig. 3 on the curve 4 in the region $L = 9 \div 10$). If this takes place indeed, it may serve as a rough indication of the fact that the appearance of proton fluxes on remote L-shells is linked with a more concrete geomagnetic setup, while the pre-history of the latter in a $\sim$12 hour time interval exerts a greater influence on the proton intensity variations in $L = 6 \div 9$.

The authors are grateful to N. Gordeyev and N. Rachetkin for conducting calculations and processing the material.

*** THE END ***

Moscow State University
Institute of Nuclear Physics

Received on 15 June 1965.

REFERENCES

[1].- I. A. SAVENKO, M. V. TEL'TSOV, V. L. MADUYEV, ET AL.- G.i A.* 5, 6, 1965.
[2].- S. N. VERNOV, I. A. SAVENKO, M. V. TEL'TSOV, P. I. SHAVRIN.- Ib. 5, 4, 1965.
[3].- L. A. FRANK, J. A. VAN ALLEN, H. K. HILLS.-J.Geophys.R. 69, 11, 2174, 1964.
[4].- L. R. DAVIS, J. M. WILLIAMSON.-- COSPAR III, W.H.P.Co., 365, 1963
[5].- KOSMICHESKIYE DANNYYE (COSMIC DATA).- Dek.Obz. No. 33-45 IZMIRAN, 1964.
[6].- B. L. VAN DE VERDEN.- Matem.statistika , Gl. XIII, IL ** , 1960
[7].- R. A. HOFFMAN, L. R. DAVIS, J. M. WILLIAMSON. J.Geophys.Res. 67, 13, 5001, 1962.

* Geomagnetizm i Aeronomiya (G. i A.) ** IL means "Foreign Literature".

Contract No.NAS-5-9299
Consultants and Designers, Inc.
Arlington, Virginia

Translated by ANDRE L. BRICHANT
on 30 May 1966

DISTRIBUTION

GODDARD SPACE F.C.

100 CLARK, TOWNSEND
110 STROUD
400 BOURDEAU
601 FAVA
610 MEREDITH
611 McDONALD
ABRAHAM
DAVIS WILLIAMSON
HOFFMAN KONRADI
EVANS
BOLDT VKB
SERLEMITSOS
TEEGARDEN
612 HEPPNER
NESS
SCEARCE SKILLMAN
613 KUPPERIAN
HALLAM
614 WHITE
FROST
615 BAUER
SERBU
HERMAN GOLDBERG
MAIER STONE
640 HESS
MEAD
NAKADA
NORTHROP
SPEISER
641 STERN
630 GI for SS (3)
252 LIBRARY
256 FREAS

NASA HQS

SS NEWELL, NAUGLE
SG MITCHELL
SCHARDT
DUBIN
SL FELLOWS
HIPSHER
HOROWITZ
SM FOSTER
GILL
RR KURZWEG
RTR NEILL
ATSS - T
WX SWEET

OTHER CENTERS

AMES R C

SONETT
LIBRARY

LANGLEY R C

160 ADAMSON
185 WEATHERWAX

U.IOWA

VAN ALLEN

U.BERKELEY

WILCOX

UCLA

COLEMAN

SWCAS

JOHNSON

J P L

SNYDER
NEUGEBAUER
WYCKOFF